CANMET

FOLLOW-UP ASSESSMENT OF A MULTI-RESIDENTIAL COMPLEX IN WHITEHORSE, YUKON

Canada Centre for
Mineral and Energy Technology

Centre canadien de la technologie
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PREPARED FOR

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Energy Technology Branch, Energy Sector
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Executive Summary

The Level B monitoring of Closeleigh Manor in Whitehorse, Yukon was completed in July 1992 and the final report, *Monitoring and Investigation of a Multi-Suite Residential Complex in Whitehorse, Yukon from 1988 to 1992*, was submitted to Natural Resources Canada (NRCan) in March 1993. As a result of the recommendations of that report, a number of mechanical system changes were carried out. The most significant changes were the renovations made to the domestic hot water heating and ventilation systems.

NRCan was interested in conducting a follow-up investigation to determine the building's current operation and maintenance status and evaluate any changes which had occurred since initial monitoring was completed in 1992. The investigation included interviews with the Yukon Housing Corporation (YHC), the building owner, and Whitehorse Housing Authority (WHA), responsible for operating and maintaining the building; inspections of the mechanical systems and the individual suites; and computerized monitoring of specific mechanical system components.

The investigation showed that Closeleigh Manor was being well maintained and that YHC and WHA had responded well to addressing the recommendations put forth in the March 1993 report. The interviews and inspections identified problems highlighted in the March 1993 report which had not yet been addressed, and uncovered new problems which required further investigation. The discovery of a major problem with the original space heating system piping design once again emphasized the need for thorough building commissioning.

The follow-up investigation raised a number of issues and questions which must still be addressed and answered. They are presented as recommendations and include renovation work that is to be completed, investigative work that should be carried out after the renovations are completed, and suggestions for ensuring a continued high level of building maintenance and operation.

Résumé

Le contrôle de niveau B du Closeleigh Manor, à Whitehorse (Yukon), s'est terminé en juillet 1992 et le rapport final, intitulé *Monitoring and Investigation of a Multi-Suite Residential Complex in Whitehorse, Yukon from 1988 to 1992*, a été présenté à Ressources naturelles Canada (RNCan) en mars 1993. Conformément aux recommandations du rapport, on a apporté un certain nombre de changements au système mécanique, dont les plus importants ont été les travaux de réfection des systèmes de chauffage à eau chaude et de ventilation.

NRCan a décidé d'effectuer une enquête de suivi afin d'évaluer où en sont, aujourd'hui, le fonctionnement et l'entretien du bâtiment et de déterminer quels changements ont été apportés depuis le premier contrôle, en 1992. L'enquête a été menée sur plusieurs fronts : entrevues avec la Yukon Housing Corporation (YHC), avec le propriétaire du bâtiment et avec le Service de logement de Whitehorse (SLW) (responsable du fonctionnement et de l'entretien des locaux); inspections des systèmes mécaniques et des suites; et contrôle informatisé de certains éléments du système mécanique.

L'enquête a permis de constater que le Closeleigh Manor était bien entretenu et que la YHC ainsi que le SLW avaient tenu compte des recommandations du rapport publié en mars 1993. Les entrevues et les inspections ont mis en lumière certains problèmes mentionnés dans le rapport de 1993 qui n'avaient pas encore été réglés, ainsi que de nouvelles lacunes nécessitant un examen plus approndi. La découverte d'un problème grave concernant la conception originale de la canalisation du système de chauffage des locaux a une fois de plus démontré la nécessité d'effectuer des inspections rigoureuses avant l'occupation des bâtiments.

Il reste encore à régler un certain nombre de questions et de points soulevés par l'enquête de suivi. Ils sont présentés sous forme de recommandations et incluent les travaux de rénovation à terminer, le travail d'enquête qui devra suivre les rénovations et des propositions en vue d'assurer un fonctionnement et un entretien de qualité.

1. Background

Computerized Level B monitoring of Closeleigh Manor in Whitehorse, Yukon was completed in July 1992 and the final report, *Monitoring and Investigation of a Multi-Suite Residential Complex in Whitehorse, Yukon from 1988 to 1992*, was submitted to Natural Resources Canada (NRCan) in March 1993. Based on the recommendations of that report, a number of changes were implemented in the building. The most significant changes were the renovations made to the domestic hot water (DHW) heating and ventilation systems.

2. Introduction

NRCan was interested in following-up on the investigation of Closeleigh Manor completed in 1992 by:

- determining the current operation and maintenance status;
- reviewing the recommendations for changes to Closeleigh Manor made in the *March 1993 Final Report*; and
- evaluating any changes to the building made since 1992.

The information that was to be gathered and the areas that were to be investigated during this project were determined based on input from NRCan who initiated and funded the original project, the Yukon Housing Corporation (YHC) who owns the building, and the Whitehorse Housing Authority (WHA) who operates and maintains the building.

3. Interviews with the Building Owner and the Building Operator

A representative from YHC, the building owner, and from WHA, responsible for operating and maintaining Closeleigh Manor, were interviewed regarding the successes and/or failures of the technology that was incorporated into this building as a result of it being designed to meet the R2000 Program technical requirements that were in place in the late 1980's. Their comments are presented in Table 1.

Table 1: Building Owner and Building Operator Comments

Building Envelope	• If constructing Closeleigh Manor today, the air barrier and insulation system would not be changed. • The double front door entry is a definite advantage as it prevents icing that occurs with other apartment entryways. • An attic design requiring a sprinkler system would not be used again. The liability resulting from a system failure is just too great.
Windows	• In general, the window units have not been a problem. Problems that have occurred were due to poor installation. • Latched casement windows are not always effective since, if a latch is left down and the window is closed against it, the result is a poor seal and air leakage. Smaller seniors, and those using walkers or in wheel chairs cannot reach the upper latch especially if there is furniture in front of the window.

Windows (cont'd)	• Over time, crank style windows become stiffer and more difficult to operate, especially for seniors. An awning style window with a lever type opener would be more appropriate. • The hardware manufacturer is no longer in business so that replacement is difficult. • If installed today, the windows would be triple glazed and argon filled with vinyl frames. We are unsure about Low-E coatings, especially for seniors, because of controversies regarding reduced lighting levels through high performance windows.
Sound Proofing	• Closeleigh Manor has the best sound rating and the fewest noise complaints of any of the YHC apartment buildings and it is one of its best features. • The sound insulation, concrete topped floors and other sound proofing techniques would all be repeated.
HVAC - General	• It appears that the oversizing of the mechanical system resulted from a misinterpretation at the design stage of what YHC actually wanted. YHC requested a "quality" system and, in fact, the mechanical contractor promised to deliver a "cadillac" system. However, the contractor held the philosophy in achieving this that "if one is good, then two is better". • Today, the promise of a "cadillac" system immediately raises flags for YHC who make sure that a "cadillac" system is one that is as energy efficient as possible and yet can be maintained and serviced by local contractors at a reasonable cost.
Space Heating	• Oil-fired boilers would be installed again. Although, propane systems have lower maintenance costs, the problems with freeze-up in very cold weather far outweigh any advantages. • The efficiency of the space heating system cannot be optimized because the chimney, piping etc. were originally sized for 10 boilers whereas only five remain and even these are not used to full capacity. Recently, at outdoor temperatures of -40°C, the space heating to the building was being maintained with only 2 boilers. The other 3 boilers were not operating at the time and DHW was being provided by the backup DHW system.
Domestic Hot Water	• A backup DHW tank would be installed from the beginning. • The heat exchanger system that was originally installed was a poor choice because it is not familiar to local contractors and is not as efficient and effective as a dedicated system. • A stand alone, oil-fired hot water tank that can easily be serviced, and replaced if necessary, would be chosen.
Ventilation	• Supply air ducts in the suites could have been better located. Beds and chairs often end up under existing ducts resulting in complaints of drafts and grilles being blocked. • If building again, we would not install a system that ventilates each suite individually. This choice has resulted in too many complaints and has required too much effort and cost to get it operating properly. • This system would be replaced with a pressurized hall system.

Ventilation (cont'd)	• Occupants in upper floor suites still open windows which results in ventilation imbalances throughout the building. • Locating the building's ventilation supply and exhaust ducts in the alley, and at ground level, was a very poor choice which has resulted, and continues to result, in tenant complaints of noise, fumes and dirt being drawn into the building. Modifications to these ducts have failed to resolve all the problems. • In addition, the location of the building's ventilation exhaust resulted in excessive icing on the wall of building. • These ventilation ducts should have been located on the roof.
Heat Recovery	• We are sold on heat recovery but not on the heat recovery systems that are currently available. • If we were considering heat recovery today, we would definitely carry out a cost benefit analysis because we do not feel that the energy savings outweigh the added cost and ongoing operation and maintenance considerations.
Other Mechanical	• The use of pneumatic system controls would be eliminated since most of the trades are not familiar with their operation and replacement parts are not readily available outside of the large centers. This type of system would only be considered again if trained personnel were available, and on call, 24 hours per day, 365 days per year. • The mechanical room is very hot during the summer months and affected the operation of the pneumatic air dryer required for all pneumatic controls. As a result, the compressor and the pneumatic dryer had to be moved out of the mechanical room. • The elevator cab and the stairwells are not large enough to accommodate a person horizontal on a stretcher so that sick or injured persons have to be transported in a sitting position.
Other - General	• One must be more sensitive to the population occupying a building. The mix of an older population and innovative technology is not a good one. • Greater consideration should have been given to electrical conservation when installing lighting, appliances, block heaters and other electrical components in the building.

4. Review of Recommendations from March 1993 Final Report

Section 6 of the *March 1993 Final Report* presented a number of recommendations for specific changes to Closeleigh Manor. This section details the status of those recommendations.

4.1 Building Envelope Recommendations

1. ***Recommendation:*** *Tenant seminars regarding the proper use of the windows should be held twice a year at the beginning of the heating and cooling seasons.*

   Current status: No seminars have taken place but work conducted during this project suggests that open windows are no longer a major concern (Section 5.3.2).

2. ***Recommendation:*** *The use of the humidifier should be limited, and possibly not used at all, in order to prevent window condensation build-up during cold weather.*

   Current status: The building humidifier is no longer used. Individual suite humidity is provided by the occupants.

4.2 Heat Recovery and Ventilation

1. ***Recommendation:*** *The boiler and space heating back-up circulation pumps should be set to operate at the same speed as the principle pumps.*

   Current status: Only the principle pumps are set up to be controlled by the variable speed controller due to the high cost of converting all pumps. Although it would be ideal to alternate pumps, the back-up pumps are currently only used if the principle pump breaks down.

2. ***Recommendation:*** *Install a sound proofing duct section in the supply ducts to Suite 104 (and possibly Suite 102) due to excessively high noise levels from the mechanical room which is adjacent to Suite 104.*

   Current status: A sound absorbing duct section was not installed. This problem was addessed in this followup-investigation.

3. ***Recommendation:*** *Retrofit several existing dampers in the air system to provide superior flow control.*

   Current status: When examined more closely during the November 1993 ventilation system renovation, the original dampers proved to be of good quality. As a result, adjustable dampers were installed in individual suites as required.

4. ***Recommendation:*** *Install dampers behind the supply air grilles in the second and third floor hallways.*

   Current status: These were installed during ventilation system renovations in November 1993.

5. ***Recommendation:*** *Install adjustable supply diffusers in those suites where air flows exceeded design tolerances. If they prove successful, install in all suites.*

   Current status: Adjustable supply and exhaust dampers were installed as required during the November 1993 ventilation system renovation and when the system was re-balanced in 1994.

6. ***Recommendation:*** *If adjustable diffusers are installed, lower the setpoint temperature of the supply air to the building's balance point temperature of 16°C in order to minimize the delivery of heated ventilation air when it is not required.*

   Current status: The supply air temperature to the building is maintained at 20°C. When the delivery temperature is less than this, occupant complaints increase and there is a higher incidence of grilles being blocked off.

4.3 Space and Domestic Hot Water Heating Systems

1. ***Recommendation:*** *The building owner and the building operator work closely with the boiler manufacturer to resolve boiler problems identified in 1993 report.*

   Current status: During the DHW system renovation in October 1994, a new furnace controller was installed, boiler nozzles were returned to their original size and the boilers were adjusted. Some of the boilers are still cycling frequently but the boiler manufacturer has yet to be contacted regarding this problem.

2. ***Recommendation:*** *The setpoint of the three-way valve should be adjusted to the original design specification of 38°C.*

   This will allow the space heating fluid that circulates throughout the building to drop to 38°C as the outside temperature rises to 21°C. During the original monitoring, the space heating fluid to the building did not drop below 55°C.

   Current status: The three-way valve is not working as intended and it is not possible to attain the original design temperature.

3. ***Recommendation:*** *Examine the thermostats and the control valves in Suites 203, 212 and 307 to determine if large differences in actual verses thermostat setpoint temperatures is caused by improper operation of these sensors.*

   Current status: These controls were never checked since concerns had not been expressed by the occupants.

4.4 Cooling System

1. ***Recommendation:*** *An assessment of the cooling system should be conducted once system operation has been verified and an operating schedule has been determined.*

   Current status: This assessment was not carried out but the building operator has experienced a problem with the system going down and would like it investigated.

4.5 Electrical System

1. ***Recommendation:*** *Retrofit hallway fluorescent fixtures with 32 Watt bulbs. Investigate retrofitting the reflector and electronic ballast.*

   Current status: Bulbs are being changed as they burn out. About 85% have been changed so far. Suite entry lights were all replaced in 1991 and to-date only three have had to be replaced. The use of reflectors and electronic ballasts has not been investigated. The building operator does not have the expertise nor the time to carry out this sort of investigation but remains open to product recommendations and a cost benefit analysis presented by expert sources.

2. ***Recommendation:*** *Retrofit vehicle plug-ins with time-of-day switching or temperature controlled switching.*

   Current status: This recommendation has not been acted on because seniors want vehicles to be ready at all hours of the day or night in case of an emergency.

5. Inspection and Assessment of the HVAC System

Subsequent to the completion of the *March 1993 Final Report*, the following renovation work was carried out on the HVAC system:

- November 1993: Numerous modifications were made to ventilation dampers, and supply and exhaust grilles.
- March 1994: The ventilation system was re-balanced. Additional supply and exhaust grilles in the suites were changes as required.
- October 1994: The piping to one boiler module was modified to provide domestic hot water (DHW) during summer months allowing the other boilers to be shut down.
- October 1994: A stand-alone hot water tank was installed to provide a backup DHW system to the existing system.
- October 1994: A Tekmar Model 528 boiler sequencing control panel was installed to replace the existing sequencing controller.

This section describes these renovations in greater detail, discusses areas of concern and questions that remain, and presents the finding of this project's investigation.

5.1 Domestic Hot Water Heating System

5.1.1 Dedicated Boiler for Summer Mode Heating

During the 1994 renovation, a number of piping and valve changes were made which allow the building operator to manually dedicate one boiler for summer mode operation. Prior to the renovation, and during the summer months when the space heating demand is greatly reduced, the bank of 5 boilers was maintaining a boiler fluid temperature required for DHW heating and the reduced space heating demand. This resulted in frequent boiler cycling and reduced boiler efficiency. Once the renovation was completed, by manually changing three valves one boiler module can be dedicated to provide the boiler fluid required to heat domestic hot water. The return water from the hot water tank heat exchanger mixes with the water going through the other boilers and can contribute to any building space heating demand. If no building heating is required, the 3-way valve which controls the temperature of the space heating circulation fluid. will prevent any building heating and reduce the circulation temperature to 38°C.

Since the dedicated boiler will be providing any space heating requirements in addition to its primary role of providing domestic hot water, the building operator will have to determine the best time of year to the switch to summer mode operation without leaving the building with insufficient boiler capacity to supply both domestic hot water and space heating. Based on his current knowledge of the building, the building operator feel the switch-over could be carried out sometime in May. It is important to note that at -40 °C two boilers were capable of meeting the building's space heating requirements.

When the dedicated boiler (Boiler 1) is in summer mode operation, it is taken off the Tekmar controller and its ontime is not recorded. The order in which the boilers are fired is based on the amount of time they have been operating as recorded by the Tekmar controller. As a result, consideration should be given to operating Boilers 2, 3, 4 and 5

only during winter mode operation, and using Boiler 1 for summer mode operation only. By doing this, boiler ontime will be distributed more equally among all boilers.

5.1.2 Back-up DHW Heating System

The back-up DHW heating system installed during the 1994 renovation, consisted of a 70 US gallon (265 L) capacity John Woods water tank with a 138,000 BTU/hr (36 kW) Beckett oil burner. The recovery rate on this tank is 131 US gallons (496 L) per hour based on a 100°F (38°C) temperature rise. On two occasions since its installation, it has been necessary to use this back-up system for short periods of time. On both occasions, the system adequately met the DHW demand. The first time it was used, the aquastat was set at 54°C (130°F) and, during peak demand, the temperature of the water to the building that the tank was able to maintain dropped approximately 10 F° . This resulted in complaints of insufficient hot water through the tempering valve located at the bathtub in each suite. The aquastat setting was subsequently raised to 60°C (140°F) and further complaints were not received.

For 3 weeks during this project, the DHW system was set up so that DHW requirements were provided solely by the backup system. Performance was monitored using the building's computerized monitoring system to assist in determining if the back-up system could be used on a year-round basis. On only three occasions during this period was the system not capable of meeting the building demand. At these times, however, complaints were received from the tenants about a lack of hot water. The monitored data indicated that when the DHW demand was greater than approximately 500 liters per hour the DHW supply temperature dropped from a typical temperature of about 58°C to about 48°C. Based on tenant complaints, it was evident that this water temperature is not sufficient to compensate for the effects of the valves that temper the bath water in each suite. As a result, the building operator has indicated that the stand-alone DHW tank will only be used as a back-up system.

5.2 Boiler and Space Heating System

5.2.1 Boiler Controller

The Tekmar controller is a microprocessor based unit which regulates the boiler supply water temperature based on outdoor temperature. The controller measures the outdoor temperature and, as outdoor temperature becomes colder, raises the boiler supply temperature. The building operator selects a preset *Heating Curve* which calculates the number of degrees the supply water temperature is raised for each degree the outdoor temperature falls. The controller also has the capability of shutting off the boilers and the system pump when the outdoor temperature is above the preset *Warm Weather Shutdown Point (WWSD)*.

The oil-fired boilers at Closeleigh Manor are not able to take advantage of this WWSD feature because they require a minimum return temperature of 60°C (140°F) in order to prevent the corrosion and sooting resulting from low flue gas temperatures. Therefore, a *Minimum Supply Temperature* is set on the Tekmar controller which maintains the supply temperature to the minimum setting when the outdoor temperature drops below the WWSD point and holds it there until the outdoor temperature becomes cold enough to require operation of the heating curve.

5.2.2 Three-way Valve

In order to prevent the overheating of the building in warm weather, Closeleigh Manor was designed with a boiler fluid circulation loop and a building space heating circulation loop. Transfer of boiler supply fluid to the space heating circulation loop was meant to be accomplished through a 3-way valve which is also controlled by outside temperature. As outside temperatures increases, the temperature of the fluid in the space heating loop decreases down to the minimum design temperature of 38°C.

The building operator indicated that this valve had not been working properly for some time. The temperature of the space heating fluid to the building was being maintained by using a bypass pipe that connected the boiler loop directly with the building circulation loop. Upon investigating this problem further, Howell-Mayhew Engineering (HME) discovered that there was no connection from the return piping of the space heating loop directly to the boiler loop. This connection is required in order to provide circulation loop relief as the 3-way valve moves from its closed, or *no heat* position, to its open, or *full heat* position. Currently, when the valve is in an open position the circulation loop return piping is completely blocked off and circulation is not possible.

This problem was reviewed by J.M. Bean & Co. (JMB), the company that has designed and overseen all of the mechanical renovations at Closeleigh Manor. They reported that in order for the 3-way valve to modulate properly, it is necessary for the building circulation loop return piping to have a direct connection to the boiler circulation loop. This allows the space heating water to return to the building loop or to the boiler loop, depending upon the position of the 3-way valve.

If the 3-way valve is in the *full heat* position, the bottom port of the valve should be 100% open to boiler water and the side port should be fully closed to building return water. In this mode of operation, the return water from the building must be allowed to return to the boiler circulation loop at some location. If the valve is in an intermediate, modulating position, some of the return water will pass through the side port and mix with boiler water, while the remainder of the return water continues to return to the boiler loop.

A site visit to Closeleigh Manor by JMB determined that the piping connection between the return water piping and the boiler circuit does not to exist. JMB will be working with the building operator to ensure that this problem is rectified. Once the necessary piping changes have been made, it will be necessary to ensure that the 3-way valve is modulating properly and controlling the temperature of the space heating fluid to the building as originally designed. The building operator will be able to use the computerized monitoring system to verify proper operation.

5.2.3 Boiler Cycling

Some of the boilers still appear to be cycling more frequently than would be expected under normal operating conditions. The building operator and the building's heating contractor had thought this problem was due to uneven circulation rates through the boilers causing the boilers to shut off on high limit. JMB indicated, however, that the boilers are piped in a *reverse return* configuration which automatically equalizes the length of connecting pipe for each boiler module so that circulation flows through each

boiler should be the same. Circulation flow rates can be verified by measuring the temperature rise across the boiler but there is currently no provision in the piping to take these measurements. The building operator is considering having self sealing temperature plugs installed when the piping changes are made to the space heating / boiler circulation loops (see Section 5.2.2). JMB's recommendation is that the building operator work with the manufacturer to address this problem. This would best be done after piping changes have been made and it has been determined that the 3-way valve is operating properly.

5.2.4 Barometric Damper Settings and Chimney Oversizing

While conducting the mechanical system investigation, HME noticed that, even with none of the boilers firing, the barometric dampers were open a significant amount indicating an overdraft situation. As part of the work of this project, the boilers were setup and adjusted in January 1997 when the outdoor temperature was -40°C. At this time, the heating contractor adjusted the barometric dampers so that they were closed when the boilers were off. This required removing all weights from the dampers. The negative pressures at the boiler outlets were measured and were satisfactory.

The oversized chimney was discussed with JMB who were not overly concerned. Although heat is being lost up the chimney, this is heat from the mechanical room where the temperature has always been too hot. In addition, they did not feel there was a practical and economical way to retrofit the chimney.

5.3 Ventilation System

5.3.1 Mechanical Room Inspection

A visual inspection of the ventilation system revealed no problems. Flow measuring stations were cleaned and when the overall flows were measured using the building's computerized monitoring system it was discovered that there was no flow through one of the two supply branches. Further investigation revealed that the damper for this branch had been worked on some months earlier. The damper handle had been removed during the course of the work and had not been positioned correctly when it was reinstalled. As a result, although the damper handle indicated that the damper was fully open, it was actually fully closed. The problem was easily resolved and flow was restored through this supply branch.

The monitoring system then indicated that there was balanced supply and exhaust flows to the building. The computerized monitoring system had not been operational for a number of years prior to this project and, as a result, the means to discover the damper problem had not been available to the building operator. Since the monitoring system is not likely to be maintained and operated in the future, the building operator has arranged to have magnehelic gauges installed on the supply and exhaust ducts in the mechanical room. In this way, it will be possible to determine at a glance whether or not there are flows and whether or not the flows are balanced thereby indicating the presence of a system problem.

5.3.2 Suite Inspection

An inspection of each of the suites was conducted. Changes to supply and exhaust grilles, and damper modifications carried out during the November 1993 renovation and the March 1994 balancing were visually inspected and air flows were verified using a velometer. In general, the tenants were pleased with the current status of building ventilation and only a few concerns were expressed. The problems that were occurring are discussed in Section 6.

In addition to the interior inspection of the suite, a building walk-around was conducted at different outdoor temperature to assess the number of windows that were being kept open and the effect that the open windows may have on building ventilation. The monitoring program completed in 1992 indicated that air leakage across the well-sealed building envelope increased significantly when windows were open and it had been recommended that regular education seminars be given to encourage tenants to keep windows closed as much as possible. The data collected is presented in Table 2.

Table 2: Open Windows During Heating Season

Date	Time	Temp.	Conditions	Floor	Number of Open Windows		
					Cracked	<75mm	>75mm
21-Oct-97	1630h	-10°C	Overcast	3rd 2nd Main	11 8 None	2 1 None	4 None None
3-Jan-97	1000h	-42°C	Overcast	All	None	None	None
19-Jan-97	1630h	-10°C	Overcast	3rd 2nd Main	7 2 None	4 1 1	1 1 None

Comments on Table 2:

- At outdoor temperatures around -10°C, approximately 20 percent of the windows are open to some degree with the majority of these windows only open a small amount (cracked). In very cold weather all of the windows are closed. Overall, open windows do not appear to be having a significant impact on building air leakage rates.
- Most of the open windows are on the third floor where air tends to exfiltrate from the building. As a result, occupants would not experience incoming air to the same degree as on lower floors and would tend to open windows more and for longer periods of time.
- The roof eaves over a number of the third floor open windows were stained a yellowish brown clearly showing the exfiltration that is occurring. In these cases, the occupants are smokers and the windows are obviously opened frequently.
- Discussions with tenants who typically open windows indicated that they enjoyed this connection with the outdoors and were not prepared to change this practice.

5.4 Cooling System

Due to the time frame of this project (it concluded the end of March), it was not possible to address questions that have been raised by the building operator concerning the operation of the air conditioning system. When the air conditioning system has been operated in the past, unexplained shutdowns have occurred. The building operator would like to monitor a number of ventilation and air conditioning system parameters in an attempt to determine to cause of these shutdowns. HME will set up the monitoring task to measure the parameters requested by the building operator so that he will be able to assess system operation during the cooling months.

HME recommends that an overall assessment of cooling be carried out to determine air conditioning energy consumption and the potential for raising the cooling initiation setpoint from the current setting of 19.5°C to a higher setting of, perhaps, 24°C.

6. Suite Inspection

An inspection of each suite was carried out that included:

- supply and exhaust grilles and flows;
- noise and dust emissions from supply ducts.
- occupant indoor air quality concerns;
- thermostats and heating control valves; and
- windows - including weatherstripping, latches, frames and sealed units;

A detailed list of the problems encountered in each suite is presented in Appendix A.

Comments on Suite Inspections

- About one-half of the suites had window related problems with the majority of these problems associated with the latches and/or frames. The top latches were almost always a problem and typically did not catch the window and draw it tightly against the weatherstripping. Sometimes this was directly related to a warped frame but in most cases it was difficult to determine it the problem resulted from a warped window or misaligned hardware.
- The heating controls in suites 102, 207, 210, 302 and 304 need to be serviced.
- Suites 104, 201, 212 and 301 had significantly reduced or no supply and/or exhaust flow through the grilles. The dampers on the ducting to each of these suites should be checked and adjusted accordingly.
- Only suites 201 and 308 had some of the supply grilles blocked.
- Suites 210, 302, 308 and 311 showed evidence of significant dirt being introduced with the ventilation air. The problem was definitely more noticeable on the third floor suggesting that dirt is being picked up from inside the building and not from the filtered outside air entering the ventilation system.
- Suites 104, 206 and 306 had significant ventilation fan noise being introduced through the supply grilles. JMB also inspected these suites and has recommended a duct silencer that should alleviate these problems.

7. Operation and Maintenance Review

7.1 Fuel and Electricity Consumption

As part of this follow-up investigation, fuel and electricity consumption for Closeleigh Manor was gathered from the utility companies. Consumption information was also obtained for another YHC apartment complex, *Greenwood,* which has 36 suites and is a non-R2000 building with an oil-fired heating system and a pressurized hall ventilation system. The consumption data for a number of years is presented in Table 3.

Table 3: Oil and Electricity Consumption at Closeleigh vs Greenwood

	Closeleigh	Greenwood	Closeleigh	Greenwood	Closeleigh	Greenwood
Heating season	1992/93		1994/95		1995/96	
Fuel consumption (L)	57,170	64,413	57,117	62,232	58,525	68,273
Calendar year	1992		1994		1996	
Electric consumption (kWh)	307,920	222,960	305,040	240,120	315,840	212,760

Comments on Table 3:

- The Closeleigh Manor electrical data includes all of the commercial electrical use.
- Greenwood has 6 additional suites but, according to YHC, is similarly sized.
- The Greenwood ventilation system is often not operating due to mechanical failures and/or complaints of noise. The Closeleigh system is operating continuously.

A more detailed comparison of this data was not within the scope of this project. In order for such a comparison to provide meaningful information, it would be necessary to gather more detailed information on Greenwood and investigate more thoroughly how oil and electricity are being used in each building.

A renovation of the Greenwood ventilation system is planned for completion in 1997. Once this renovation is complete and a system is installed that provides continuous ventilation system operation, the opportunity exists to make a comparison of this non-R2000 building with Closeleigh Manor. It would be necessary to carry out a preliminary investigation of each building in order to ensure that similar fuel and electrical consumption parameters are being compared.

7.2 Repair and Maintenance Costs

A detailed list of HVAC system repair and maintenance costs from October 1992 to October 1996 are included in Appendix A. A cost summary is presented in Table 4.

Table 4: Summary of Repair and Maintenance Costs

SYSTEM	TOTAL COST	COST PER YEAR
Ventilation	$2,711	$678
Heat Recovery	$2,361	$590
Air Conditioning	$206	$52
Space/DHW Heating	$16,278	$4069

Comments on Table 4

- If the ventilation system repair and maintenance costs are to be compared to other buildings, it is important to note that the Closeleigh Manor system operates continuously throughout the year. This, of course, will result in greater wear on system components and higher service costs.
- Over one half of the heat recovery system costs were due to the servicing, and eventual replacement, of the system's circulation pump. Otherwise, the system pays for itself in the heat that it recovers each heating season.
- Maintaining the glycol solution and flushing the system accounted for about 60 percent of the space and DHW heating system costs. Some of the other system costs have resulted because of problems inherent in the initial design of the system.
- The costs are based on invoiced work from outside contractors and do not include the cost of the time spent by WHA personnel in maintaining the system. The building operator estimates he spends an average of 2 hours per week in the mechanical room.

Detailed information on the repair and maintenance costs for the rest of the building are not available since most of this work is carried out by WHA personnel and not outside contractors. Between the building operator and his assistant an average of 3 hours per week are spent maintaining the rest of the building.

8. Conclusions and Recommendations

Overall, Closeleigh Manor is being well maintained and is performing well. The Yukon Housing Corporation (YHC), the building owner, and the Whitehorse Housing Authority (WHA), responsible for operating and maintaining the building, have responded well to addressing the recommendations put forth in the final report on the Level B computerized monitoring investigation carried out from 1988 to 1992.

This follow-up investigation has been very valuable for a number of reasons:

- The interviews with the building owner and the building operator provided valuable insights into the advantages and disadvantages of the technology incorporated into this R2000 building (see Section 3). The interviews emphasized the need to keep systems as simple as possible and to use technology that can be serviced by local contractors.
- The interviews and a review of the status of recommendations made in the *March 1993 report* (see Section 4) alerted Howell-Mayhew Engineering (HME) to existing problems that had not yet been addressed and to new problems that had to be investigated. All of these problems were then dealt with in this follow-up investigation.
- An investigation of operational problems with the 3-way valve connecting the space heating and boiler circulation loops uncovered a major flaw in the original piping design which has prevented the space heating system from operating as originally intended. This problem is discussed in detail in Section 5.2. Once addressed, a number of space heating system problems that the building operator has encountered since the building was completed should be resolved. The discovery of this problem once again emphasizes the need for thorough building commissioning.

- Computerized monitoring of modifications to the domestic hot water heating system answered a number of questions posed by the building operator as to how the system should be operated. It was confirmed that the stand-alone hot water tank installed in October 1994 does not have the capability to meet peak DHW demands and should, therefore, be used only as a back-up system. In addition, the follow-up investigation allowed HME and the building operator to clarify the proper use and operation of the boiler dedicated for domestic hot water heating during summer mode operation. This is discussed in detail in Section 5.1.
- Computerized monitoring also revealed that there was no ventilation flow in one of the supply branches and emphasized the need to install gauges in the mechanical room that would allow the building operator the visually verify supply and exhaust flows and overall system balancing.
- The inspection carried out in each of the suites uncovered a number of smaller problems relating to the windows, ventilation system and space heating system which, when addressed, will reduce tenant complaints and improve overall system performance (see Section 6). It also emphasized the value of conducting this type of inspection annually in order to address problems when they are still minor and before they generate an occupant complaint.
- Finally, the project provided the opportunity to collect and organize information on fuel and electricity consumption, and on repair and maintenance costs. This information will be valuable to YHC and WHA in evaluating the Closeleigh technology for use in other buildings.

8.1 Recommendations

The issues and questions that remain regarding the operation and maintenance of Closeleigh Manor are addressed in the following recommendations:

- It is recommended that the list of problems that were identified during the suite inspections and presented in Appendix A be addressed as part of the ongoing maintenance of the building. It is further recommended that a similar suite inspection be carried out on an annual basis.
- It is recommended that silencers be installed in the supply ducts above the ceiling of Suite 104. Bob Overland of JMB has recommended a product and provided installation instructions that should address the noise problems experienced in Suites 104, 206 and 306.
- It is recommended that the building operator arrange to have magnehelic gauges installed in the ventilation supply and exhaust air ducts in order to be able to visually verify system flows and balancing.
- It is recommended that the building operator complete the space heating system piping modifications proposed by JMB. Once the modifications have been completed, it is recommended that the temperatures across the 3-way valve be monitored by the computerized monitoring system to ensure that the valve and, hence the space heating system, is operating as intended.
- It is recommended that the building operator follow through with the boiler manufacturer or representative to address the cycling concerns that have persisted

over the last number of years. This work should be carried out once the space heating system piping modifications have been completed.

- It is recommended that the building operator experiment with the dedicated boiler to determine the best time of the year to switch it to summer mode operation. The computerized monitoring system can be used to determine boiler ontime and fluid temperatures and ensure that the dedicated boiler is capable to meeting the building's domestic hot water and space heating needs.
- It is recommended that the building operator determine the ontime of the dedicated boiler during summer mode operation and decide whether or not the dedicated boiler should be also operated during the heating season. It may be better to operate it only during summer mode so that it is not overused relative to the other boilers.
- It is recommended that an assessment of the cooling system be conducted to address shutdown concerns expressed by the building operator and to determine the potential for raising the cooling initiation setpoint temperature.
- It is recommended that operational procedures regarding the used of the dedicated boiler during summer mode and heating season operation be documented and posted in the monitoring room for subsequent building operators. Similarly, operational procedures for operation of the cooling system should be prepared and posted.

APPENDIX A

1. Deficiency List Resulting From Suite Inspections
2. HVAC System Maintenance Costs

DEFICIENCY LIST RESULTING FROM SUITE INSPECTIONS		
SUITE	VENTILATION	DEFICIENCY NOTED
301	Exhaust flow	Very little flow through kitchen exhaust; dampers should be checked
	Supply flow	Flow has occurred in both directions from bathroom exhaust; seems that flow into bathroom has occurred during strong south winds;
302	Dirt	Occupant inserts filters on supply grilles to catch dirt
306	Noise	Noise from supply grilles
308	Dirt	Supply and exhaust grilles covered with cellophane because of problems with dirt entering through ventilation system
308	Dirt	Dirt showing on walls around supply grilles
201	Supply flow	Living room supply grille blocked
204	Draft	Blanket at base of entry door to stop cold air
206	Noise	Noise from supply grilles
208	Fumes	Bedrooms supply grilles blocked to prevent fumes from entering
210	Dirt	Occupant cleans off dirt on wall around supply grilles
212	Exhaust flow	No exhaust flow in bathroom; dampers should be checked
104	Supply flow	No flow from supply grilles
	Exhaust flow	Slow flow through exhaust grilles
	Noise	Noise through grilles from mechanical room
	HEATING	
302	Controls	Valve cap in bedroom needs to be fixed
304	Controls	Thermostat off but indicated temperature was 25C; zone valve and thermostat should be checked
207	Controls	Thermostat off but indicated temperature was 23C;keeps window open because it is never cool enough; check zone valve and thermostat
210	Controls	Thermostat setpoint 6C lower than indicated and heat still being supplied; bedroom window open for cooling; check thermostat and zone valve
102	Controls	Thermostat setpoint 4C lower than indicated; heat still being supplied; bedroom window cracked for cooling; check thermostat and zone valve
	WINDOWS	
301	Latches	Some top latches do not work
302	Opener	Dining room window doesn't close tight
305	Latches	Some top latches do not work
309	Opener	Living room window needs adjustment so can fully open
311	Opener	Bedroom window will not fully close
201	Frame	Living room window warped
204	Latches	Some top latches do not work
	Frame	Living room window warped
205	Frame	Living room window warped
210	Frame	Frame warped so living room window leaks especially with north wind
211	Latches	Some top latches do not work
212	Latches	Some top latches do not work
101	Latches	Some top latches do not work
102	Latches	Some top latches do not work

HVAC System Maintenance Costs - October 1992 to October 1996

SYSTEM	DATE	PROBLEM ADDRESSED / WORK COMPLETED	COST
Ventilation	Oct-92	Replace defective time clock - AHU 2 and 3	$129
	Jul-93	Replace seized motor - AHU1	$1,177
	Feb-94	Clean supply and exhaust grilles	$139
	Nov-94	Replace exhaust fan motor - garbage room	$276
	Jan-95	Clean coils AHU1 and EF1	$161
	Oct-95	AHU1 shut down due to power bump	$193
	Nov-95	Clean AHU1 and EF1 rads and ductwork	$321
	Aug-96	Replace belts AHU1 and EF1	$147
	Oct-96	Air lock in heating coil	$168
		TOTAL	$2,711
Heat recovery	Sep-93	Air lock	$112
	Oct-93	Supply and add glycol	$1,476
	Oct-93	Air lock in heating coil	$134
	Dec-94	Glycol loop pump (P11) - Broken coupler	$60
	Apr-95	Supply and install glycol to top up system	$1,402
	Oct-95	Glycol loop pump (P11) - leaking seal	$434
	Jan-96	Replace glycol loop pump (P11); supply and add glycol	$2,696
	Jul-96	Glycol loop pump (P11) - Broken coupler	$147
		TOTAL	$6,461
Air Conditioning	Oct-95	Fan shut down on air conditioning unit	$59
	Sep-96	Fall shutdown of air conditioning	$147
		TOTAL	$206
Heating	Nov-92	Transfer pump off on reset - possible power bump	$107
	Nov-92	Replace defective guage in boiler room	$64
	Jan-93	Pump on Boiler #1 leaking air	$42
	Jun-93	All boilers off; Replace 5 pump couplings and one relay	$318
	Jul-93	Boilers backdrafted - replace 3 pump couplings	$110
	Jul-93	Boilers, pumps and fans shut down due to power bump	$128
	Jul-93	Boiler circulation pump (P1) shut down on reset	$42
	Aug-93	Leaking seal on circulation pump (P3)	$198
	Dec-93	Drain, flush and fill heating system; bleed air	$4,344
	Dec-93	Three boilers down - repair control panel	$96
	May-94	Replace motor and coupler - boiler #5	$264
	Nov-94	Boilers off; plugged filters; transfer pump	$86
	Nov-94	Full boiler room service	$608
	Jan-95	Clean boiler #1 - completely filled with soot	$412
	Jan-95	Clean other boilers found plugged with soot; increase combustion air to boiler room; problem found to be exhaust side hatch cover had not been replaced	$718
	Jul-95	Install bypass switch for boiler #1 on Tekmar controller	$107
	Oct-95	Remove, adjust and reinstall 3-way valve	$1,204
	Nov-95	Clean boiler breaches	$321
	Dec-95	Vibration in boiler circulation pump (P1)	$86
	Dec-95	Check 3-way valve and adjust travel	$278
	Jan-96	Boiler servicing	$834
	Jun-96	Repair leaking seals in boiler and building circulation pumps P1 and P3	$1,811
		TOTAL	$12,178